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Research Article

Analysis of Fire Safety Depending on Opening Status of Gymnasium Door

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Abstract:

The study, in an effort to minimize damage caused by fire in gymnasium, used XX gymnasium blueprint as a fire simulation program to perform fire safety analysis based on opening status of gymnasium door found at the time of fire. First, it was revealed that when the door was left completely closed and induced no airflow even a bit, the temperature surpassed 60℃at 45 seconds and peaked at about 200 seconds after the outbreak. Additionally in 100 seconds after the outbreak, the permissible visible distance of 5m was exceeded. Second, it was found that when the door was opened 50% and induced airflow, the temperature surpassed 60℃ at 50 seconds and peaked at around 180 seconds after the outbreak. In addition, in 120 seconds after the outbreak, the permissible visible distance of 5m was surpassed. Finally, it turned out that when the door was completely left open and induced airflow, the temperature exceeded 60℃ at 55 seconds and peaked around 180 seconds after the outbreak. What's more, in 150 seconds after the outbreak, the permissible visible distance of 5m was surpassed.

Keywords: Gymnasium, door, visible distance, fire simulation, fire safety

1. Introduction

The gymnasium is getting bigger and more spacious, occupying large real room incorporating a diversity of sports facilities. The gyms are increasingly leaving air conditioning and heating facilities, sanitation facilities and electric facilities to be operated indoors to deliver user convenience, exposing them to the risk of fire.[1] If fire breaks out for mismanagement of such facilities, fire detector should be arranged to promptly send alarm to occupants.[2] The reason that building fire prevention and safety performance is growingly valued is that if fire breaks out in a building-dense area, it would be able to grow into a bonfire as the inter-building space is cramped.[3]

It is hard to partition indoor space to prevent fire as the facilities feature spacious plane structure and mobile partitions designed to secure spacious convenient space, and installation of pipe duct and electric shaft is likely to stoke the spread of fire as the heat and smoke are swiftly moving vertically and horizontally because of Airstack effect.

The study, under the assumption that fire breaks out in a gymnasium, directly subjected XX gymnasium located in XX city, XX Province, to investigation by using fire simulation program "FDS" to analyze how heat, smoke and visible distance caused by fire are moving outside based on the building's door size so that countermeasure may be set up against fire.

Cho Seong-jin(2015)[4] uses simulation analysis to investigate effective way of developing safety measure for sports event audience by delving into safety awareness of people attending sports event. Kim Gwang-hyun(2017)[5] elicits maximum figure incorporating characteristics based on gymnasium utilization methods to investigate evacuation safety in the event of fire outbreak and develop ways of upgrading evacuation period.

Cho Seong-jin(2015) and Kim gwang-hyun(2017) suggested ways of systematically managing viewers' safety awareness and identifying issues in detail based on fire incident in an effort to upgrade evacuation time. According to preceding study, if fire breaks out in a gymnasium, this could lead to complicated situation as people rush to exit door in drove. So the focus was given to establishing safety awareness among viewers to bring order to such situation. However, there is a need to investigate characteristics of fire whose smoke, heat and toxic gas depend on exit door size if fire breaks out to public gymnasium frequented by a large number of people.

The study aims to investigate fire characteristics to minimize damage to people in affected building if fire breaks out to gymnasium by categorizing flame and smoke flow variables. The study involves fire simulation program to identify spread of fire and aims to minimize fire-induced damage by allowing flame and toxic gas to flow fast out of the gym through outlet, passage and exit. To that end, the study saw blue print regarding XX gymnasium which actually exists for modeling and analyzed temperature change, smoke density and combustion increase at the time of fire outbreak to verify risk of combustion increase and develop ways of minimizing fire-induced damage possibly seen in passage and exit area.

2. Fire Simulation

This aims to pre-identify behavior of fire in order to set up safety and fire prevention plan and brace for fire outbreak. Fire simulation is the technology to figure out human injury, building safety, fire behavior and evacuation path in the aftermath of fire based on experiences accumulated and computer data.[6] Fire simulation involves statistical model regarding fire risk assessment and mathematical model regarding thermodynamics and fluid mechanics, which include Cfast(Zone Model) and FDS(Field Model). FDS(Fire Dynamics Simulator) represents Field model, which was developed by BFRL (Building and Fire Research Laboratory) of National Institute of Standards and Technology, NIST).[7] The BFRL works on predicting variable state of fire-induced heat and smoke with code co-developed by research institute, university and enterprises, modeling phenomenon such as fire-induced heat, pyrolysis, flame developing, smoke movement and fire behavior and visualizing and interpreting variable state of combustion by-products such as heat and smoke through Smokeview.[8]

2.1 Fire scenario

2.1.1 Design drawing and model set-up

The building to be modeled by involving the use of computer program is 00 gymnasium constructed in 2004 after getting building license and construction permission in 2003, which served as convenience facilities for residents incorporating sports equipment and assemblage conditions. The building occupies area of 2,657.82 ㎡ with the building-to-land ratio of 14.92 % and comprises one basement and two floors with total floor area of3,028.71 ㎡. The basement occupies area of 326.67 ㎡ to incorporate electric and machine rooms, 1st floor occupies area of 2,373 ㎡ to incorporate sports and assemblage facilities and 2nd floor occupies area of 1,021.26 ㎡ to incorporate audience room, projection room and lighting room. On the right front side of the 1st floor is a passage connected to two exit doors. Inside the facilities lie stage and mobile basketball equipment. The 2nd floor features about 1,000 audience seats and incorporates 10m-high ceiling.

While hallway, control room and guitar room on the 1st floor do not feature sprinkler equipment, fitness room incorporates sprinkler, allowing fire-induced smoke to move out of the room through hallway.

Figure.1 shows that if fire breaks out to the 1st floor according to blue print of the 1st floor, the heat, smoke and toxic gas caused by the fire are simultaneously moving out through the hall so that people may move out of the building.

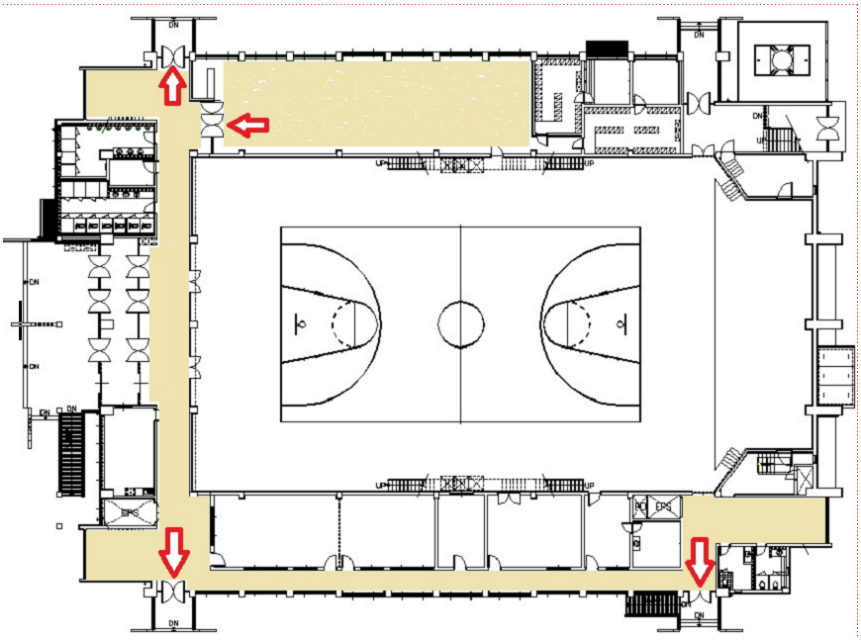
2.1.2 Blue print and model setup

The building to be modeled by using computer program is oo gymnasium which was built in 2004 after it obtained construction permission in 2003 and serves as sports facilities and place where residents get together to discuss matters. The building area is 2,657.82 ㎡, with the building-to-land ratio reaching 14.92%, comprising 1 basement and 2 floors with total ground area reaching 3,028.71 ㎡. The basement area occupies the area of 326.67 ㎡, comprising rooms for electric devices and machines. The 1st floor occupies the area of 2,373 ㎡, comprising sports facilities and meeting rooms, while the 2nd floor occupies the area of 1,021.26 ㎡ consisting of audience room, projecting room and lighting room. On the right side of the 1st floor is a passage connected to two exits, which contains stage and mobile basketball facilities, while on the 2nd floor are 1,000 audience seats and 10m-high ceiling.

While the hall, control room and other rooms on the 1st floor lack sprinkler, fitness room features one so that in the event of fire, smoke may move out to exit through the hall.

Figure.1 shows that if fire breaks out to the 1st floor according to blue print of the 1st floor, the heat, smoke and toxic gas caused by the fire are simultaneously moving out through the hall so that people may move out of the building.

Figure 1. XX gym building modelling map



2.1.3 Creation of Scenario

According to scenario based on Table 1, fire breaks out to electric heating appliance placed infront of sofa in fitness room. The study focuses on measuring change in smoke, heat, visible distance and toxic gas which varies according to the extent of fire spread.

Table 1. Scenario Conditions

Scenario	Condition
Scenario I	When fire spreads fast to sofa on the 1st floor with heating appliance placed in front of sofa still working, any manager being absent there and exit door completely being closed to have no room for airflow
Scenario II	When fire spreads fast to sofa on the 1st floor with heating appliance placed in front of sofa still working, any manager being absent there and exit door being50% left open to induce airflow
Scenario III	When fire spreads fast to sofa on the 1st floor with heating appliance placed in front of sofa still working, any manager being absent there, and exit door being completely left open to induce airflow

2.2 Assessment criteria

The performance criteria described in Table 2 are the summary of information regarding the scope of performance criteria concerning safety of human lives contained in Mark Separately 1 which regards performance-focused design method and criteria of firefighting facilities. They focus on measuring change in temperature and visible distance in which fire-induced flame and smoke can stand fire-induced heat.[9]

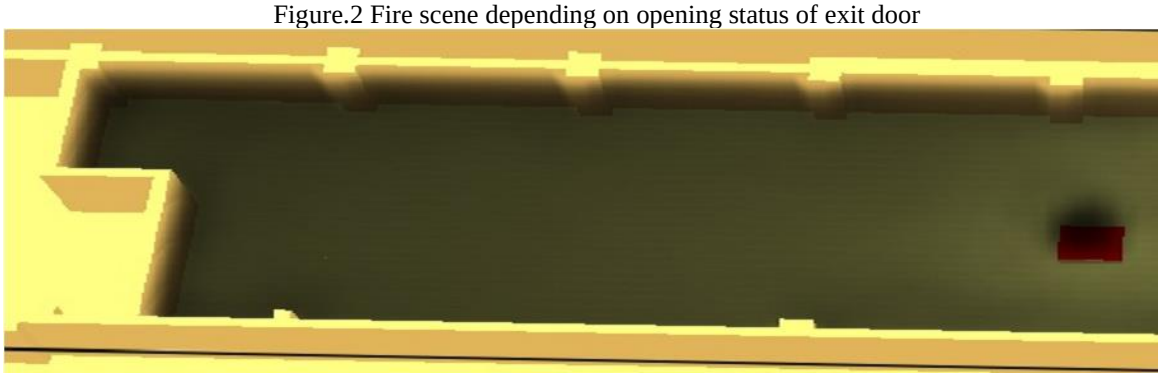
Table 2. Human safety performance criteria

Category	Performance criteria
Impact caused by heat	Less than 60℃
Permissible visible distance of sports facilities	5m

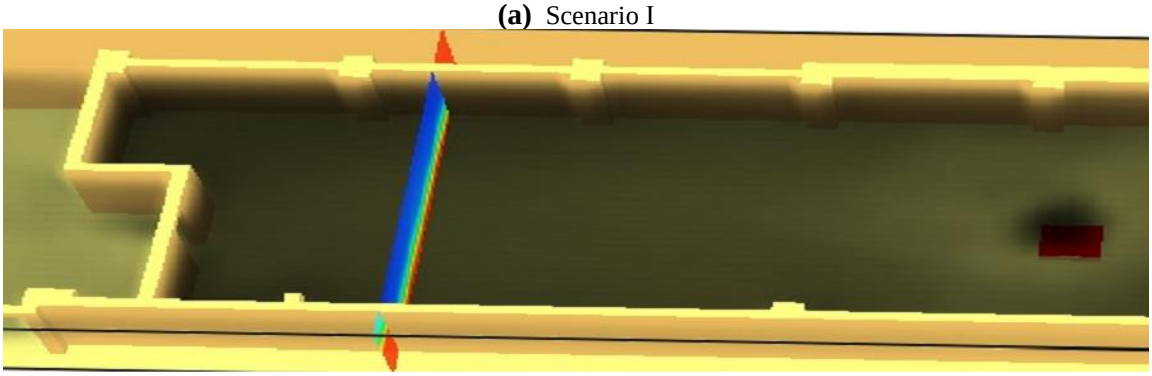
3. Result and Consideration

Fire broke out to heating appliance and spread fast to sofa placed beside it with no employee being present, releasing heat, smoke and toxic gas. The fire which broke out inside fitness facilities spread fast toward exit door, discharging toxic gas, flame and smoke. Figure.2 shows scenario-based structure and fire with smoke moving in initial stage. Scenario I shows smoke rapidly growing from the bottom with exit door completely being closed, while scenario II shows an evacuee getting out of the scene while opening one of the exit doors so smoke may move towards hallway. Scenario III shows an employee promptly opening exit doors on both sides as well as the door to outside world so smoke may move towards hallway and outside world.

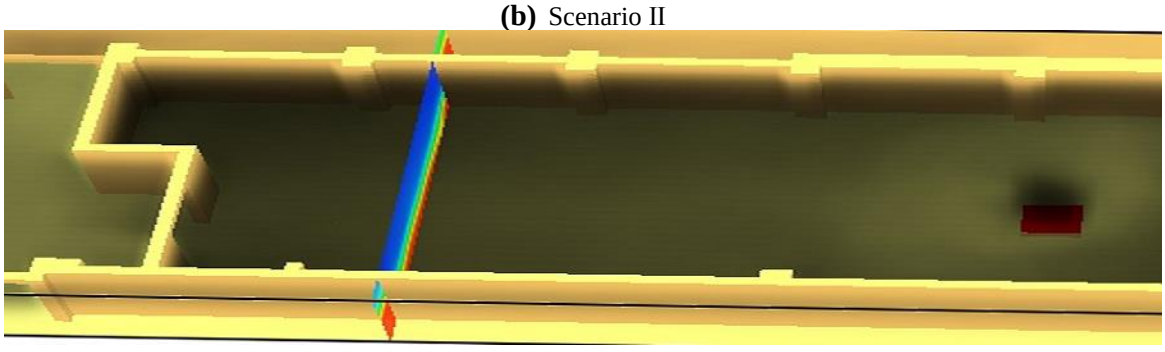
Figure.2 Fire scene depending on opening status of exit door



(a) Scenario I



(b) Scenario II

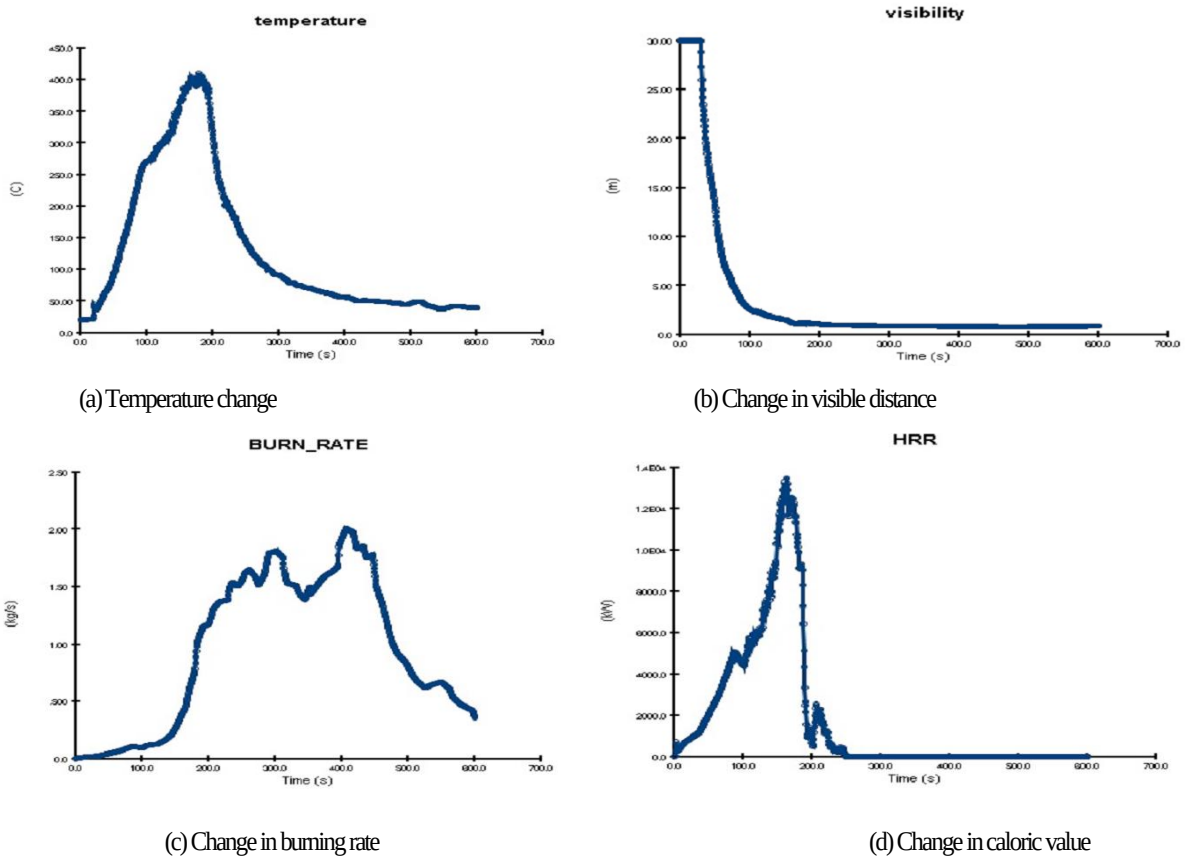


(c) Scenario III

3.1.1 Scenario I

As fire broke out to heating appliance which was heated up with no employee being present, it spread fast to a sofa placed beside it discharging heat, smoke and toxic gas. While fire occurred in fitness facilities, the smoke and flame as well as toxic gas were spreading fast towards exit. Figure. 2 shows scenario-based structure and fire fuming smoke in initial stage. Scenario 1 shows a scene of fire causing smoke going up from the bottom with exit door completely being closed, while scenario II shows an evacuee being on escape route while at the same time opening one of the exit doorsso smoke may move into a hallway. Scenario III shows an employee promptly opening exit doors on both sides of the facilities as well as the door to the outside world so smoke may move into a hall and outside space.

Figure 3. Fire behavior of scenario I



(a) Temperature change

(b) Change in visible distance

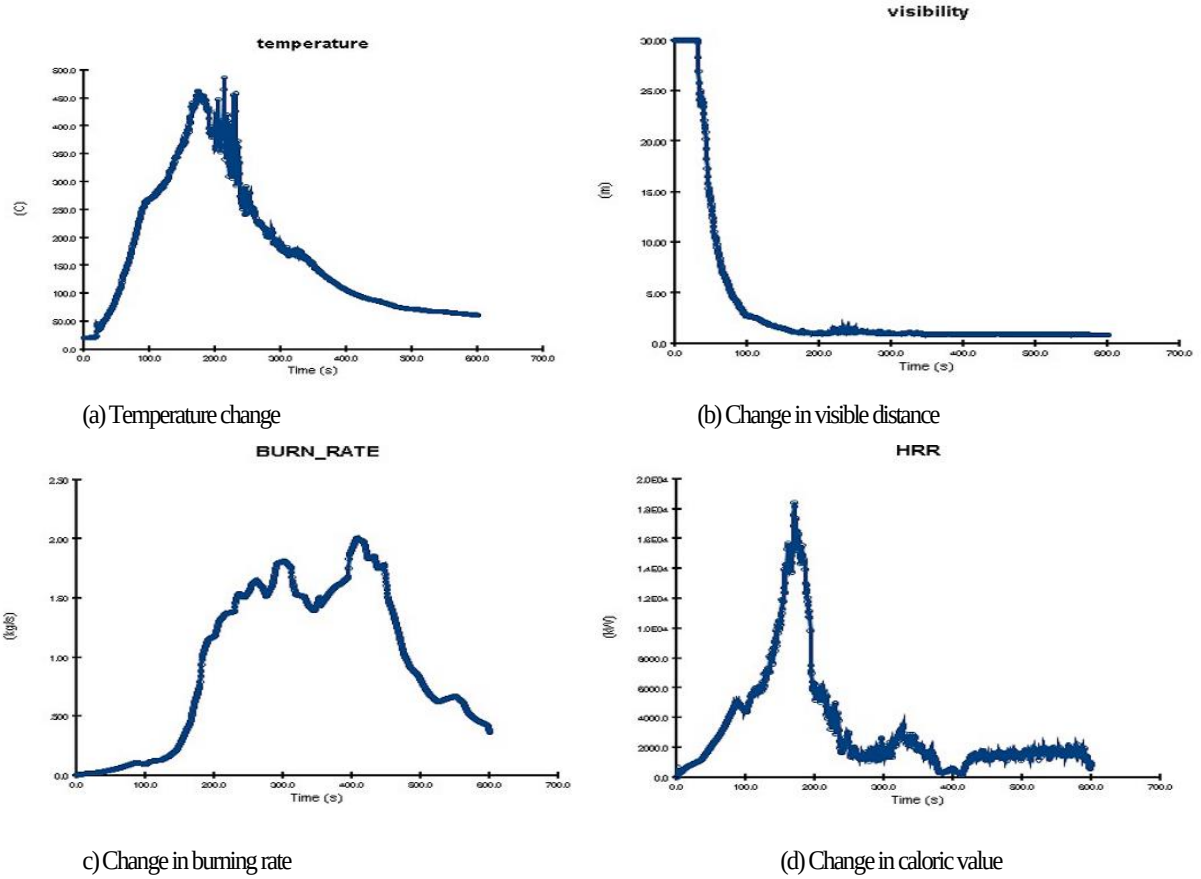
(c) Change in burning rate

(d) Change in caloric value

3.1.2 Scenario II

Scenario II shows the outbreak of fire being followed by evacuation of some occupants who opened one of the exit doors so toxic gas and smoke may move out and stay in a hallway. Figure. 4 shows a chart providing a look at change in indoor temperature, smoke movement, visible distance and combustion ratio. Figure.4(a) shows temperature rising to 60℃ in 50 seconds after the outbreak and peaking around 180 seconds with blaze being displayed and then exhibits slight change in temperature at 200 seconds or longer when exit door is left open. Figure.4(b) shows the lowest visible distance with smoke fuming out so much that things may not be discernable in 120 seconds. However, when the duration exceeds 200 seconds, visible distance gets subtler and falls below 5m. Figure.4(c) shows burning rate moving up at 160 seconds and culminating at 420 seconds and thereafter going down gradually. When it comes to change in caloric value, Figure.4(d) shows the figure rising fast in initial stage and peaking at 180 seconds and then declining dramatically at 200 seconds.

Figure 4. Scenario II's fire behavior



(a) Temperature change

(b) Change in visible distance

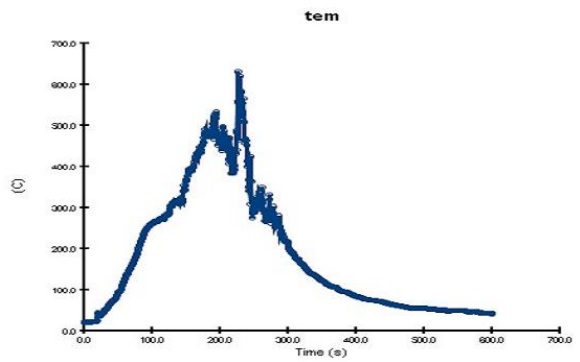
c) Change in burning rate

(d) Change in caloric value

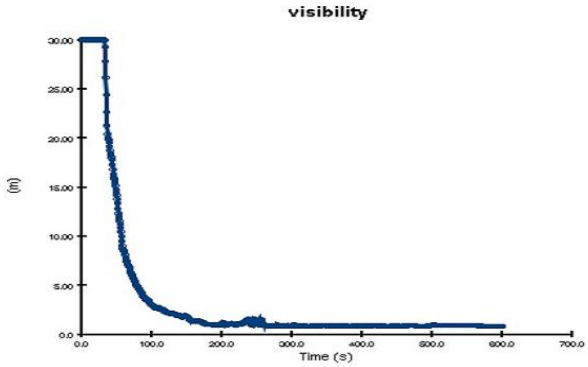
3.1.3 Scenario III

Scenario III shows the outbreak of fire being followed by employees' swift action to leave exit doors as well as door to outside world completely open so toxic gas and smoke may move fast out and towards hallway. Figure.5(a) shows a chart providing a look at change in indoor temperature, smoke movement and visible distance and burning rate. Figure.5(a) shows temperature rising over 60℃ around 55 seconds after the outbreak and peaking near 180 seconds with blaze being seen, and distinctive change in temperature which follows exit door being opened occurs when the duration exceeds 200 seconds. Figure.5(b) shows visible distance falling below 5m so that things may not be discernable in 150 seconds after the outbreak. Figure.5(c) shows burning rate rising at 160 seconds, peaking at 420 seconds and then gradually declining. As far as caloric value is concerned, Figure.5(d) shows the figure initially rising fast, peaking at 180 seconds and declining dramatically at 200 seconds and falling to zero at 300 seconds.

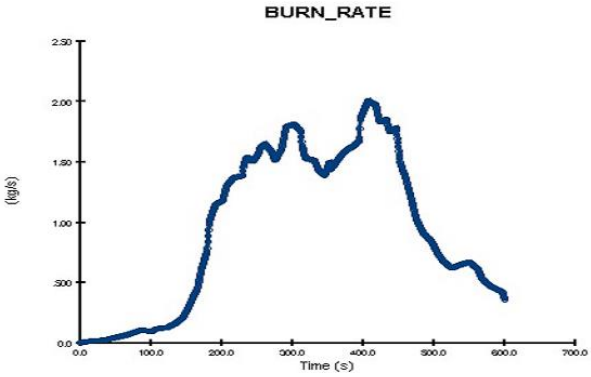
Figure 5. Scenario III's fire behavior



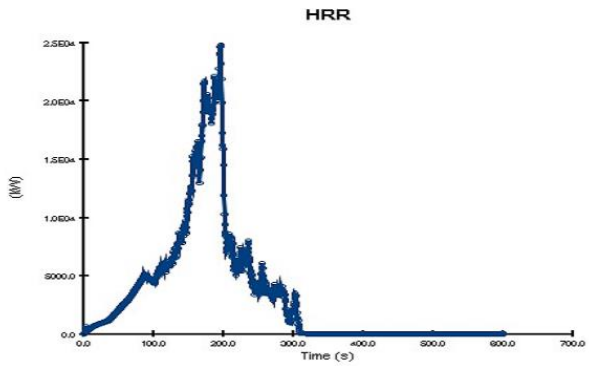
(a) Temperature change



(b) Change in visible distance



c) Change in burning rate



(d) Change in caloric value

4. Conclusion

The study focused on tracking change in temperature, visible distance, burning rate and caloric value in case fire broke out to gym facilities.

(1) Scenario I shows outbreak of fire being followed by temperature rising above 60℃at 45 seconds after the outbreak and peaking around 200 seconds. Additionally, visible distance went beyond permissible range of 5m in 100 seconds after the outbreak.

(2) Scenario II shows the outbreak of fire being followed by temperature rising above 60℃ at 50 seconds after the outbreak and peaking around 180 seconds. Additionally, visible distance exceeded permissible range of 5m in 120 seconds after the outbreak.

(3) Scenario III shows the outbreak of fire being followed by temperature rising above 60℃ at 55 seconds and peaking around 180 seconds. Additionally the visible distance surpassed permissible range of 5m in 150 seconds after the outbreak.

To lower temperature in the scene of fire, it is necessary to revise firefighting-related law currentlyconfining fire-proofing requirement applicable to sofas and seats, mainly made of textile and synthetic resin, only to business sites such as karaoke bar, pubs and no-rae-yeon-seup-jang in a way that includes cultural and assembly facilities, including gyms, as well. [10]

To secure visible distance in a gym being blurred by smoke, it is necessary to set smoke-inhibiting boundary so that smoke particles flowing from upper side may move more slowly.

In future study, it is necessary to go on researching whether carbon monoxide and carbon dioxide, both of which are caused by flame and smoke and thought to harm human health, reach beyond the baseline.

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